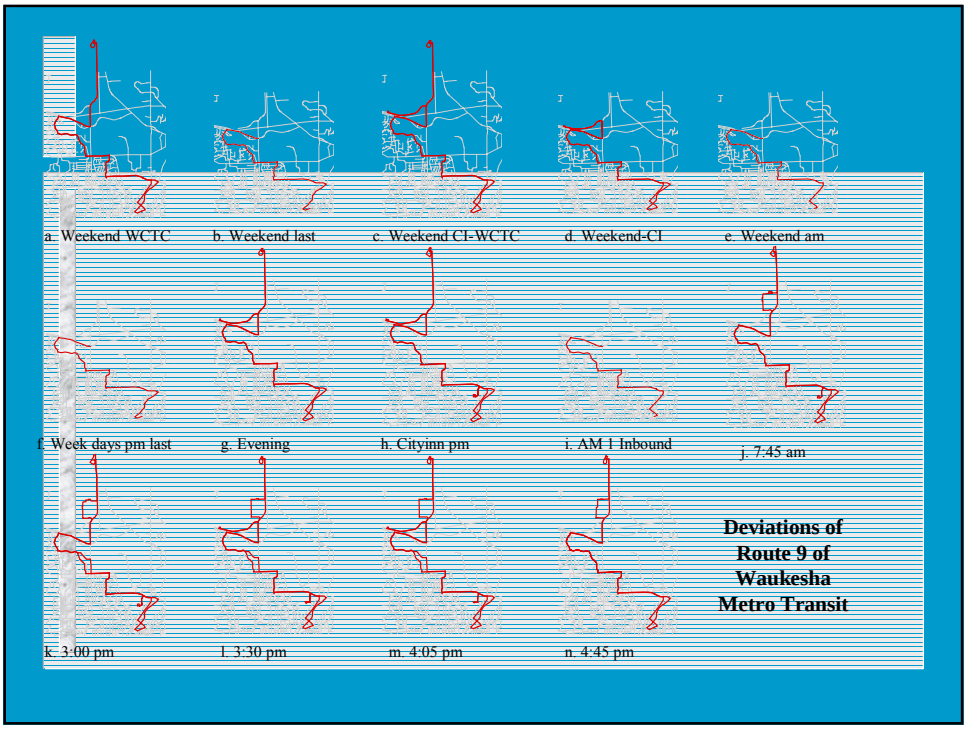
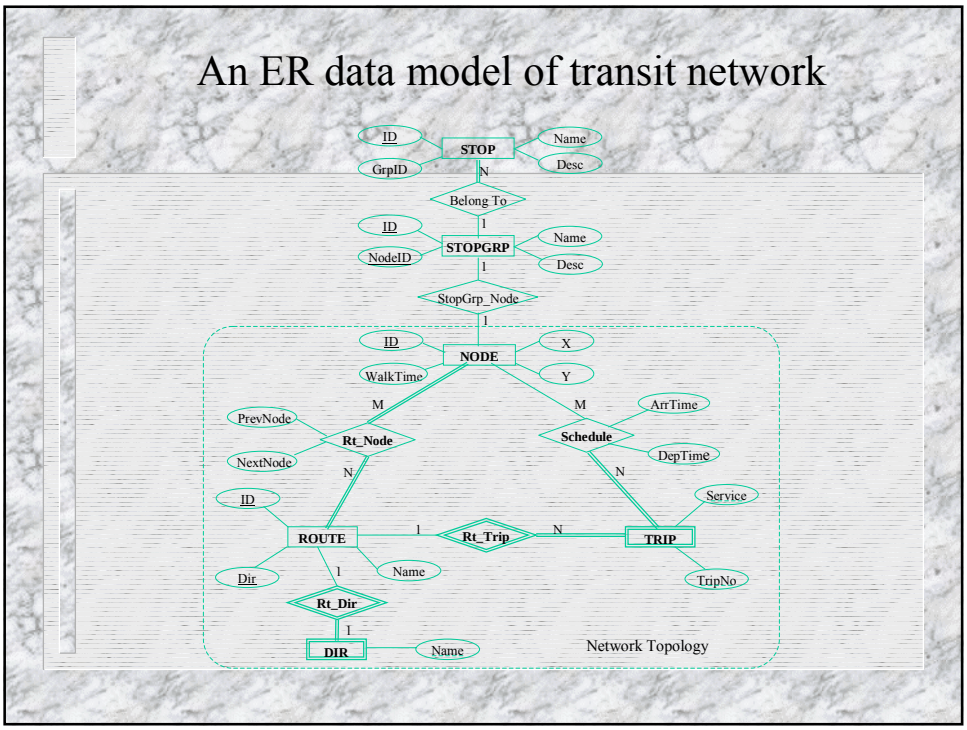
A Object-Oriented Spatial-Temporal Model for Dynamic Transit Networks

Zhong-Ren Peng, Ph.D.
Department of Urban Planning
Zpeng@uwm.edu
Ruihong Huang
Department of Geography
University of Wisconsin—Milwaukee

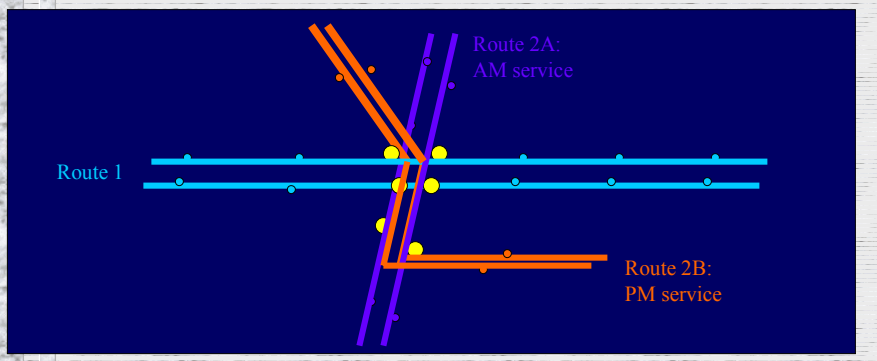
Dynamic Transit Network

- Transit service (routing and level of services) is time dependent,
- Common bus line issue,
- One bus stop serving multiple routes,
- Transit transfers depend on the arrival time of another bus,
- Express service bypassing normal stops.


a. Weekend WCTC
b. Weekend last
c. Weekend CI-WCTC
d. Weekend-CI
e. Weekend am
f. Week days pm last
g. Evening
h. Cityinn pm
i. AM 1 Inbound
j. 7:45 am
k. 3:00 pm
l. 3:30 pm
m. 4:05 pm
n. 4:45 pm
Deviations of Route 9 of Waukesha Metro Transit


An ER data model of transit network
STOP
ID
Name
GrpID
Desc
N
Belong To
1
STOPGRP
ID
Name
NodeID
Desc
1
StopGrp_Node
1
NODE
ID
X
WalkTime
Y
M
M
PrevNode
Rt_Node
NextNode
N
ArrTime
Schedule
DepTime
N
ID
Service
ROUTE
1
Rt_Trip
N
TRIP
Dir
1
Name
TripNo
Rt_Dir
1
DIR
Name
Network Topology

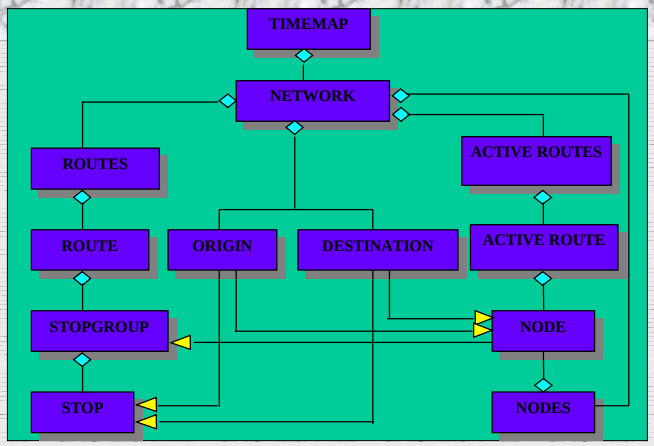
ER Model: An Example



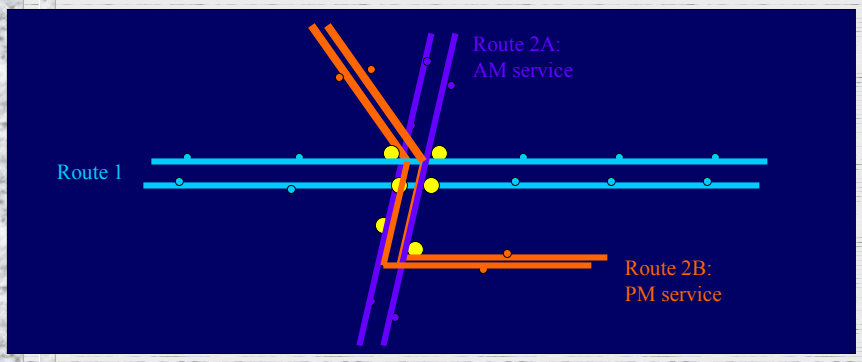
Problems with the ER Model

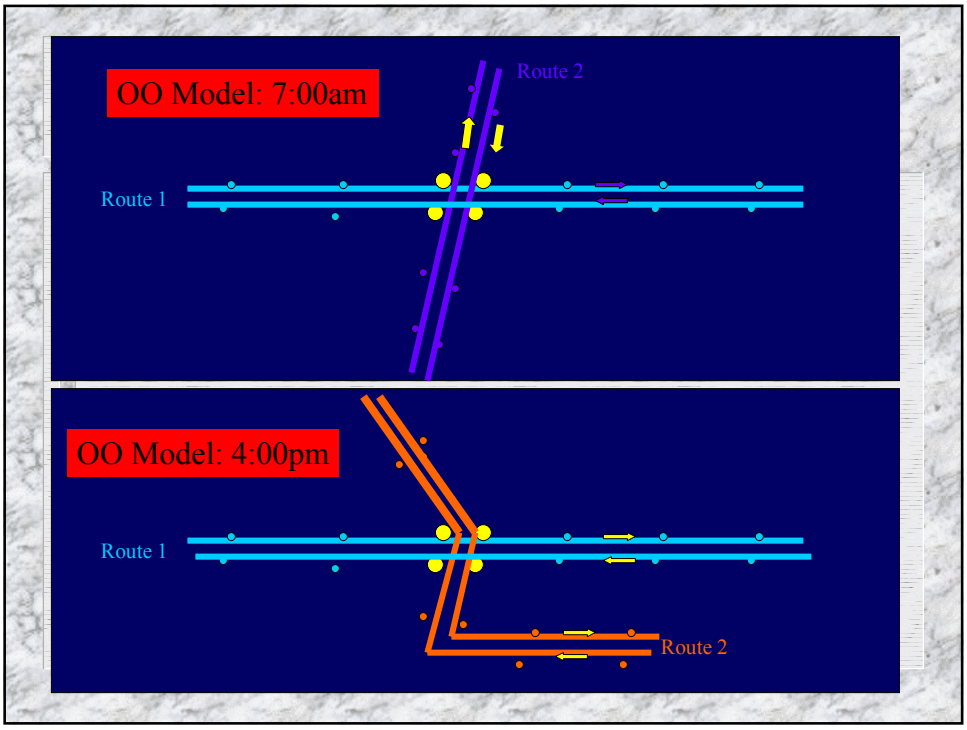
- Difficult to maintain,
- Difficult to find error,
- Difficult to update,
- Data integration is not automatic (lots of data islands and lost data),
- Slow Performance.

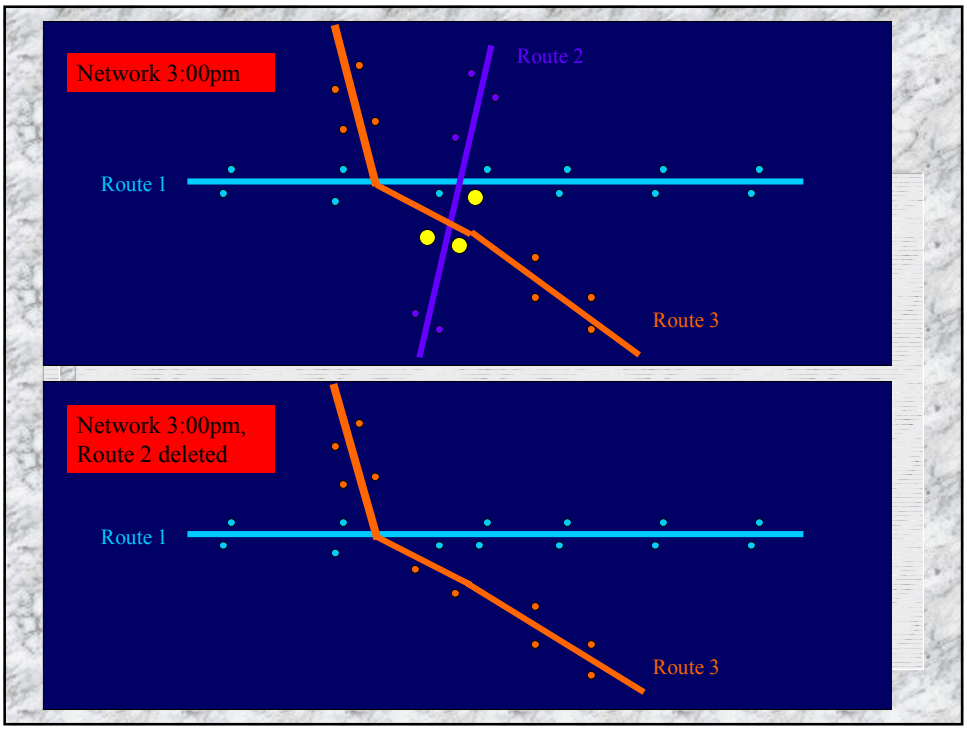
An OO Data Model of Transit Network

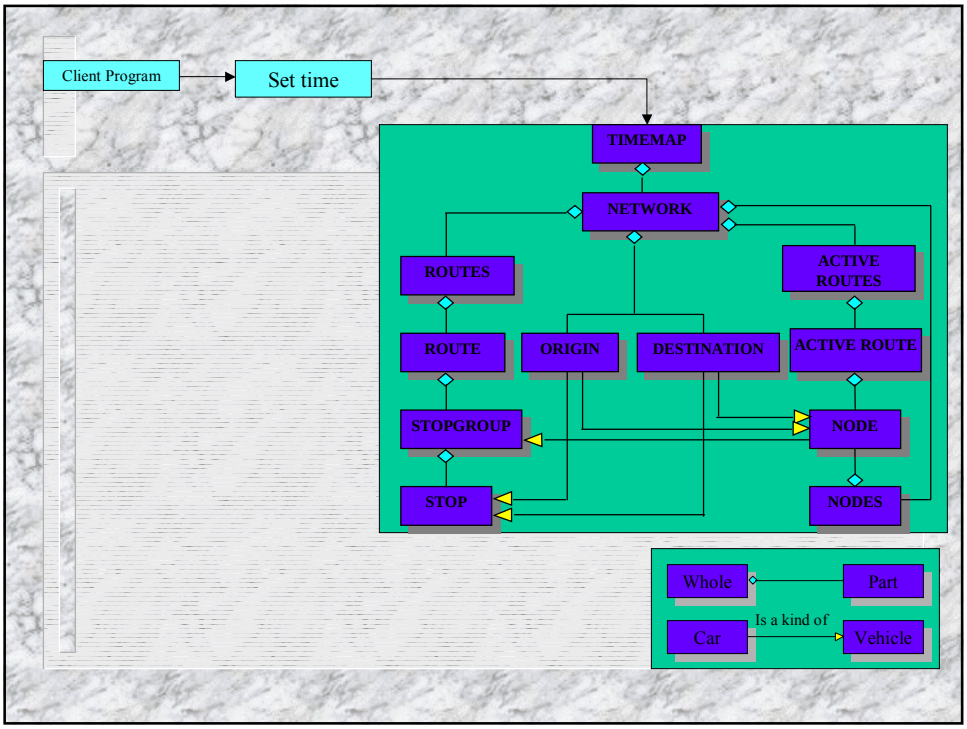


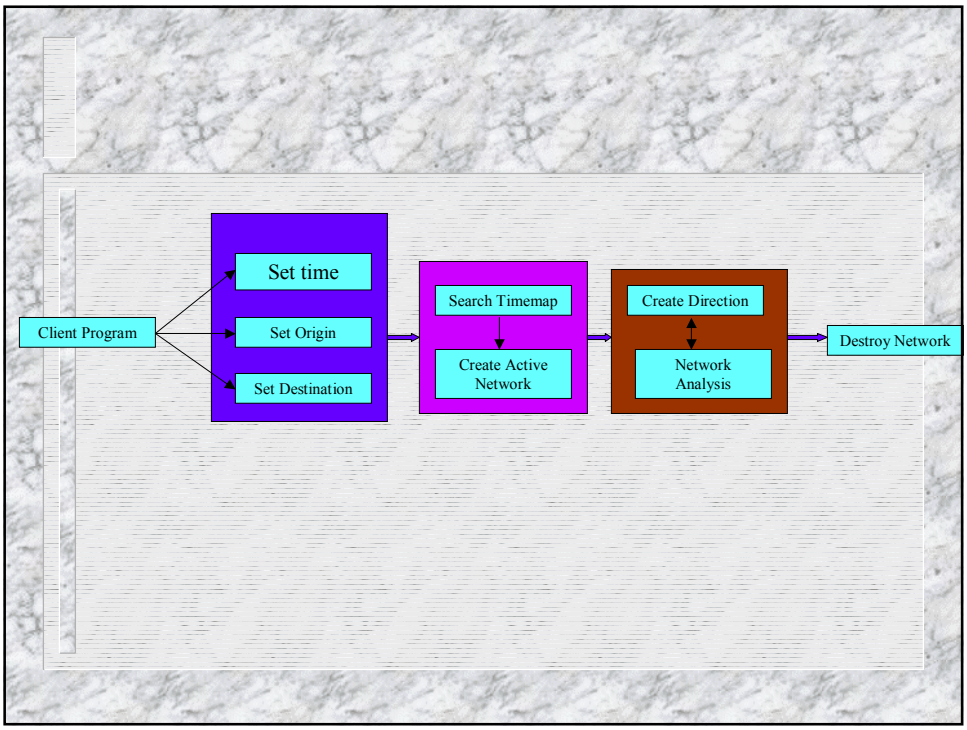
ER Model: An Example




OO Model: 7:00am
Route 2
Route 1
OO Model: 4:00pm
Route 1
Route 2


Network 3:00pm
Route 2
Route 1
Route 3
Network 3:00pm,
Route 2 deleted
Route 1
Route 3


Client Program
Set time
TIMEMAP
NETWORK
ROUTES
ACTIVE ROUTES
ROUTE
ORIGIN
DESTINATION
ACTIVE ROUTE
STOPGROUP
NODE
STOP
NODES
Whole
Part
Is a kind of
Car
Vehicle


Client Program
Set time
Set Origin
Set Destination
Search Timemap
Create Active Network
Create Direction
Network Analysis
Destroy Network

Why Object-oriented Model?

- Easier to handle dynamic changes of transit routes.
  - Different time have different properties (layouts and directions and services).
- Easier to update and maintain transit networks.
  - Easier to add, delete routes, route segments and stop locations.
  - A change in a route or route segment will not change the relationship with its upper-layer objects, therefore, all changes on the sublevel will be automatically updated for the whole network objects.
- Greater performance than the entity-relational data model.

Adding a Route Object

- A linear object.
- What is the start and end of the route (set route direction)?
- What is the traversal of the route?
- What Network in the timemap?

Adding a Stop Object

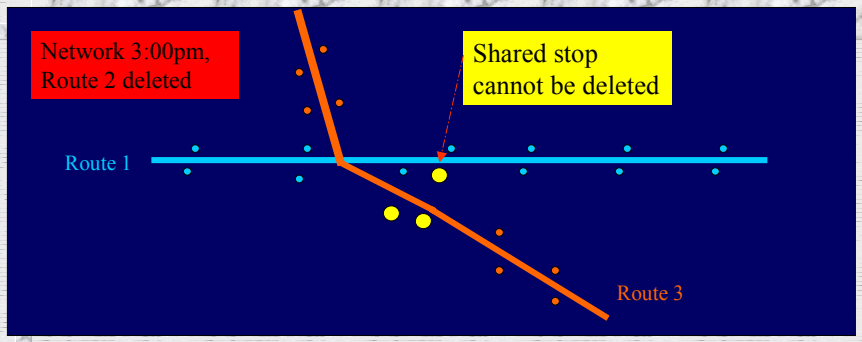
- A point object.
- What stop group?
- What route or routes does it associate with?
- Is it a transfer node?

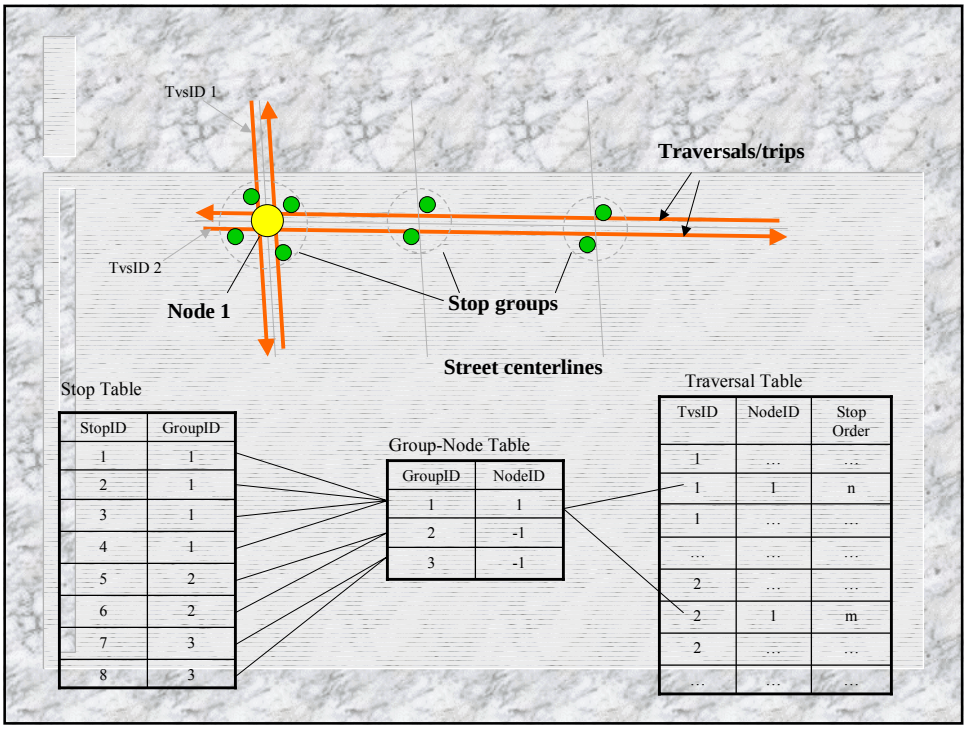
Deleting a Route Object

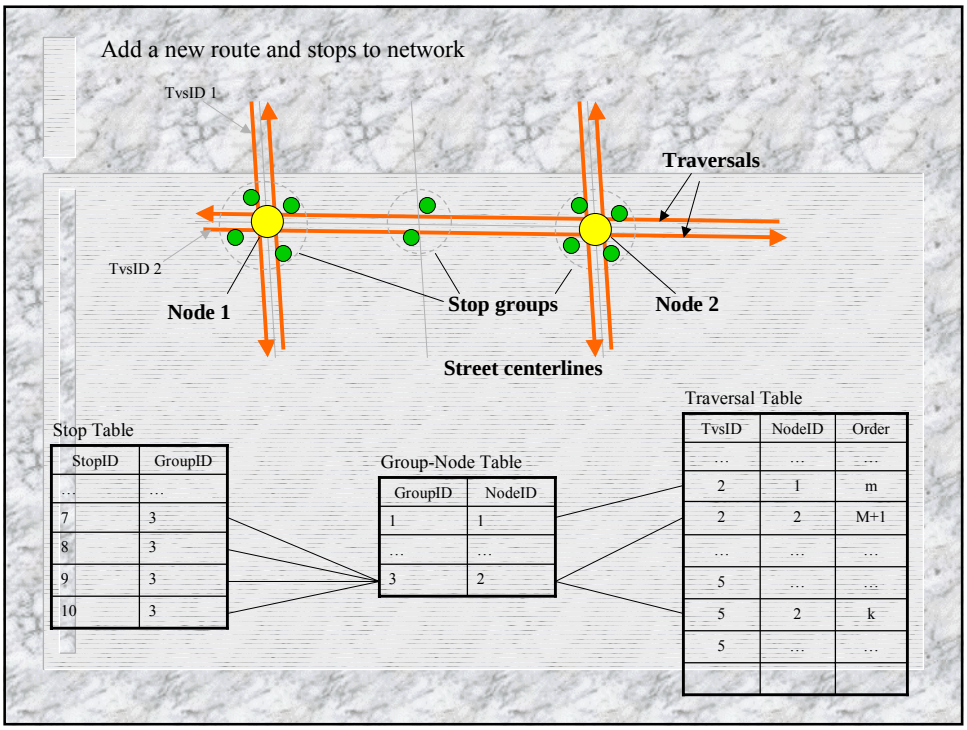
- Delete a traversal.
- Delete those stops that are associated with it but are not associated with any other routes.
- Reconstruct the transfer nodes.
- Update the network.

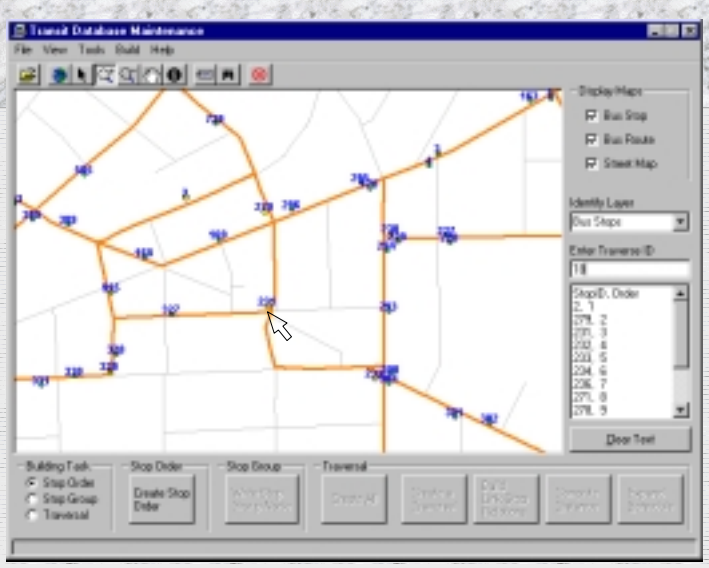
Deleting a Stop Object

- Delete the stop.
- Update the stop group database.
- Update the stop sequence database.
- Update the transfer node database.

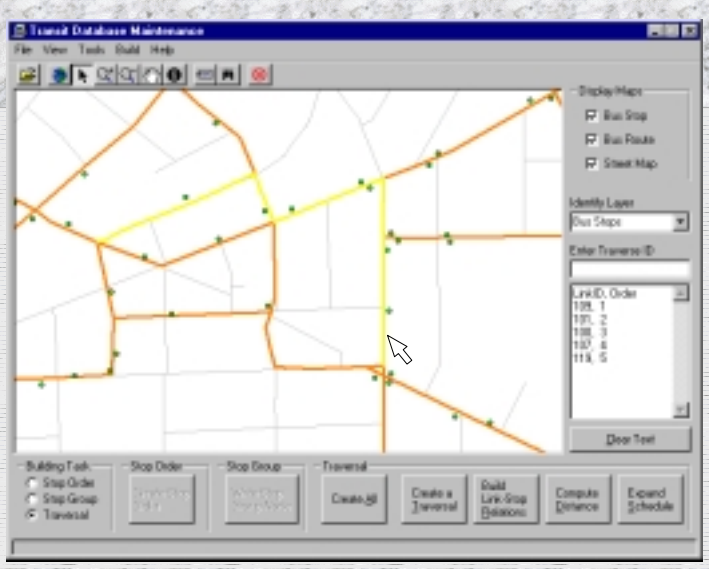



TvsID 1
Traversals/trips
TvsID 2
Node 1
Stop groups
Street centerlines
Stop Table
StopID
GroupID
1 1
2 1
3 1
4 1
5 2
6 2
7 3
8 3
Group-Node Table
GroupID
NodeID
1 1
2 -1
3 -1
Traversal Table
TvsID
NodeID
Stop Order
1 … …
1 1 n
1 … …
… … …
2 … …
2 1 m
2 … …
… … …

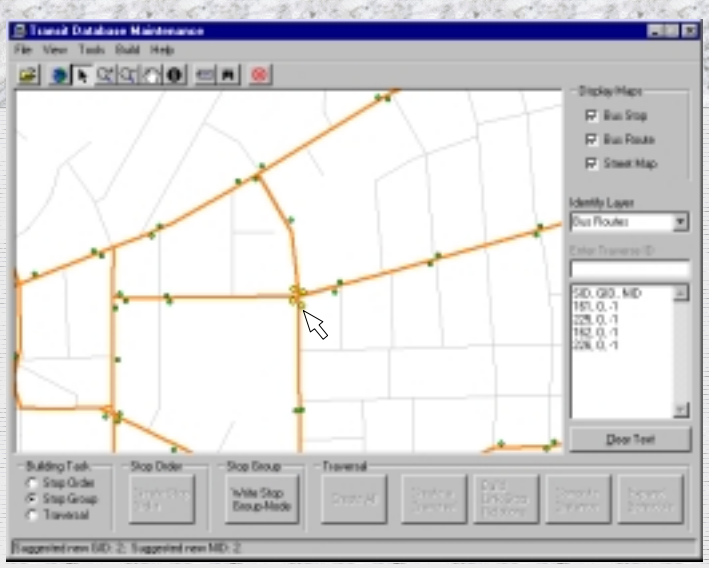

Add a new route and stops to network
TvsID 1
Traversals
TvsID 2
Node 1
Stop groups
Node 2
Street centerlines
Stop Table
StopID
GroupID
… …
7 3
8 3
9 3
10 3
Group-Node Table
GroupID
NodeID
1 1
… …
3 2
Traversal Table
TvsID
NodeID
Order
… … …
2 1 m
2 2 M+1
… … …
5 … …
5 2 k
5 … …



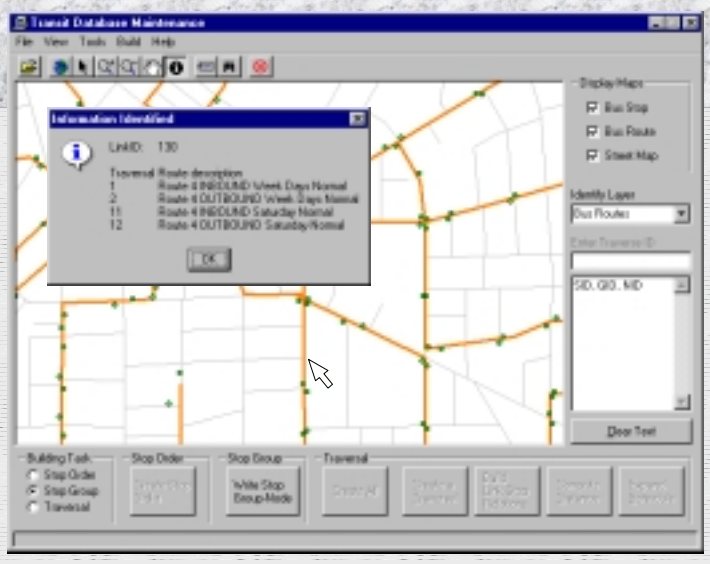
Creating a stop sequence



Creating a Traversal

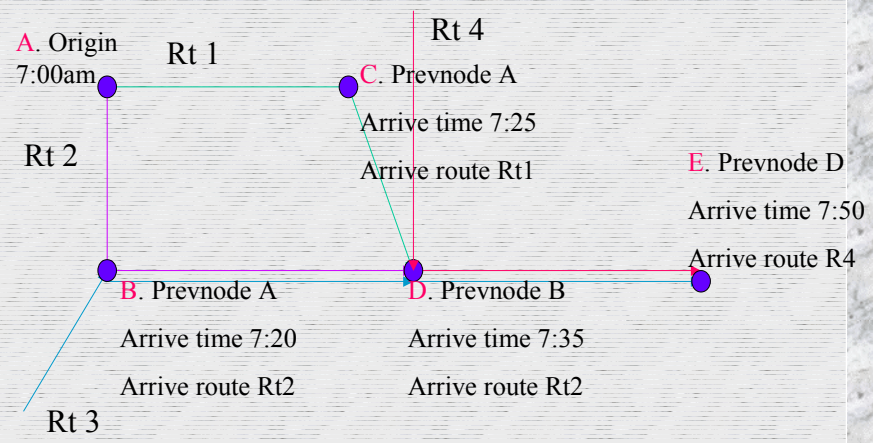


Creating stop groups and nodes

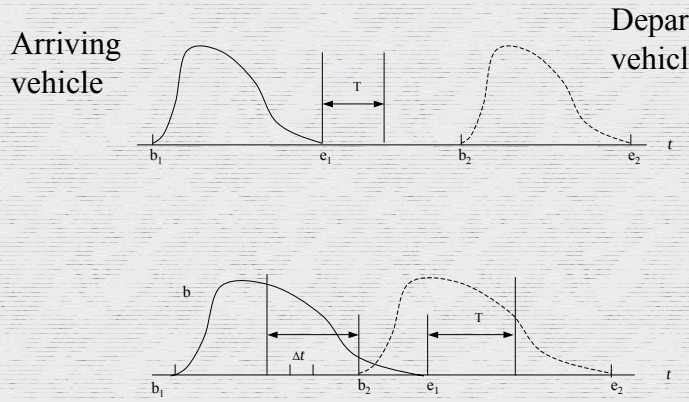


Identifying information

Path-finding Algorithm: An Example



Arrival Time Variability



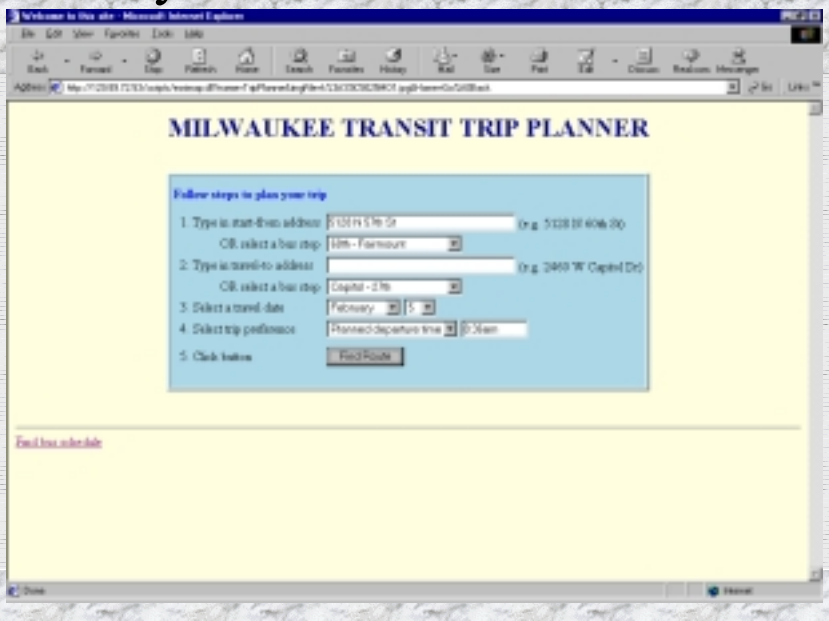
Measuring Arrival Time Variability and Probability

$$p_i = p_{i-1} + \int_{b_2 - T + (i-1)\Delta t}^{b_2 - T + i\Delta t} P_a(t)\mathrm{d}t \int_{b_2 + i\Delta t}^{e_2} P_d(t)\mathrm{d}t$$

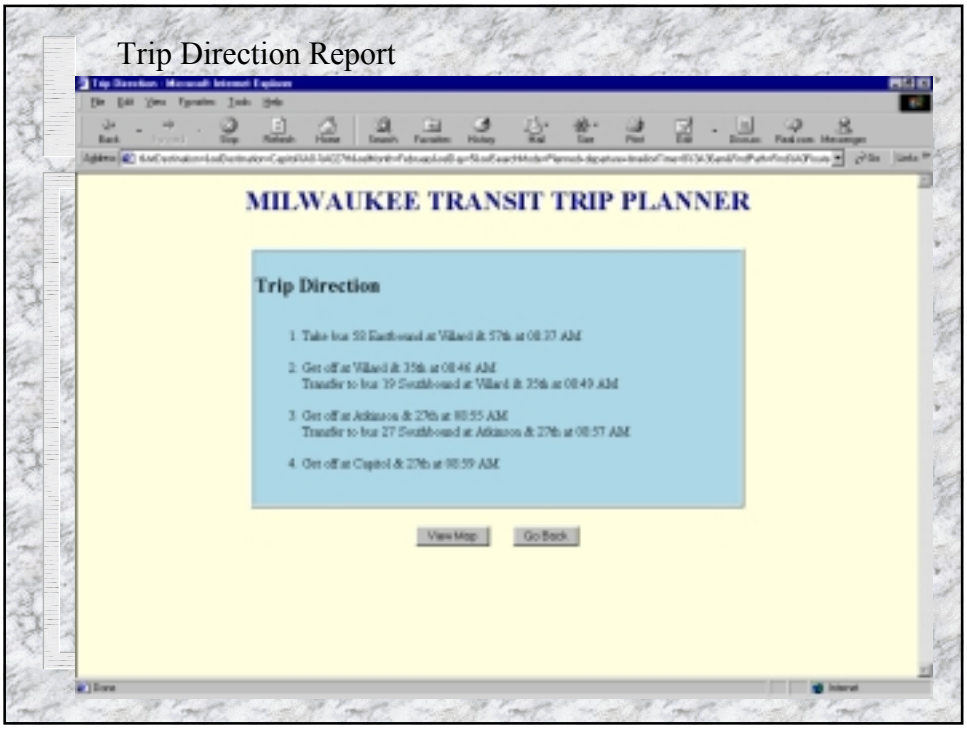
OR

$$p_i = p_{i-1} + \int_{b_2 - T + (i-1)\Delta t}^{b_2 - T + i\Delta t} P_a(t)\mathrm{d}t \left(1 - \int_{b_2}^{b_2 + i\Delta t} P_d(t)\mathrm{d}t\right)$$

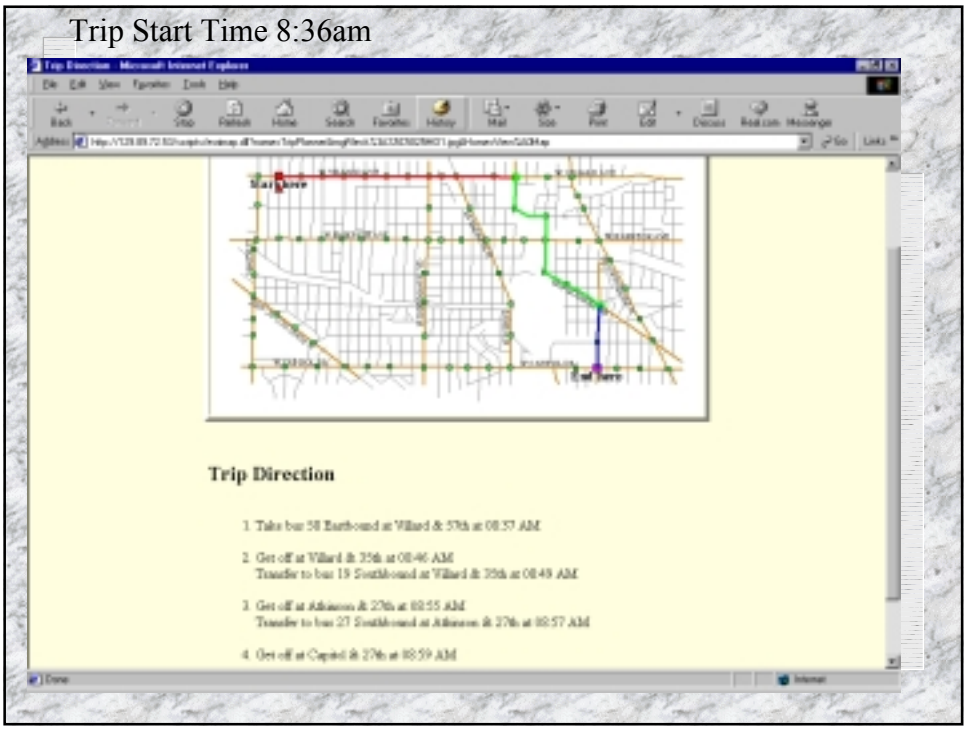
The System



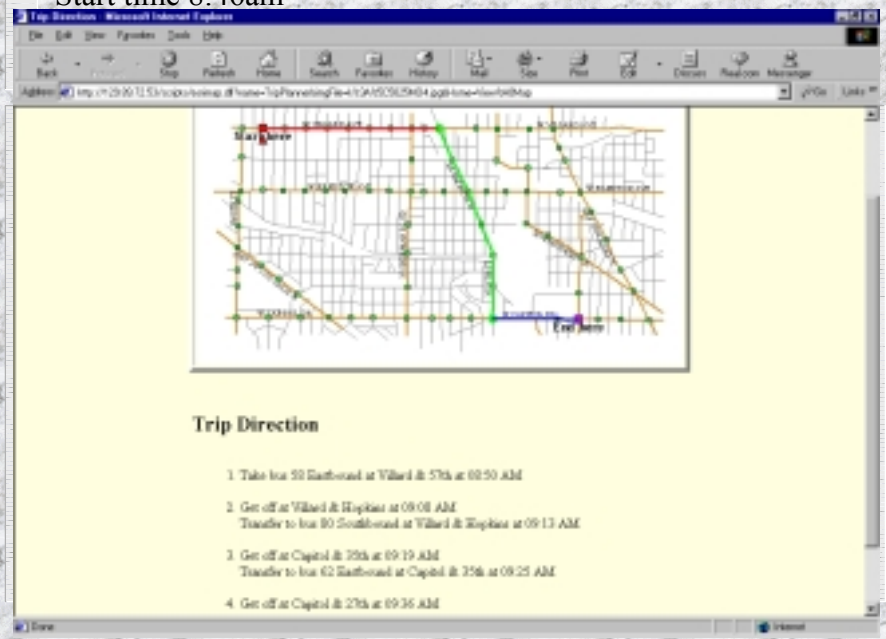
Trip Direction Report



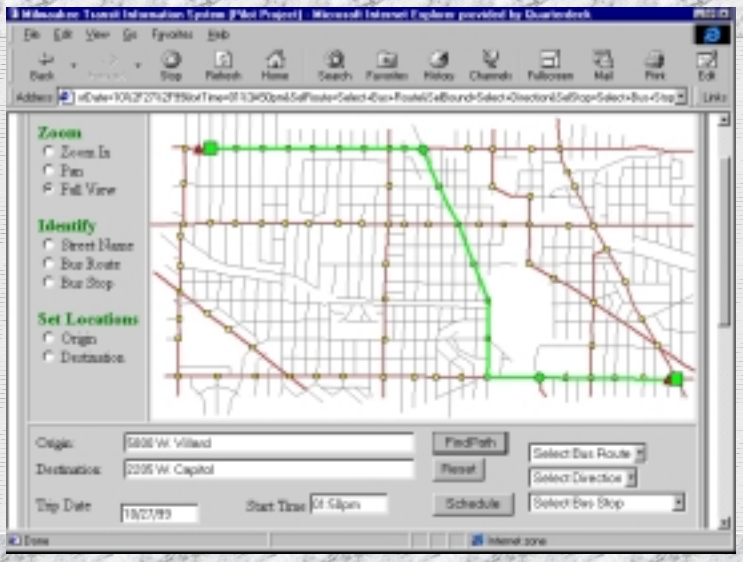
Trip Start Time 8:36am



Start time 8:46am



More sophisticated user interface



CONCLUSIONS

- The Spatial-Temporal model captures the dynamic nature of transit networks.
- The object-oriented data model design simplifies data management and maintenance.
- The object-oriented approach increase the efficiency of network analysis, including spatial search, query, and shortest path finding.